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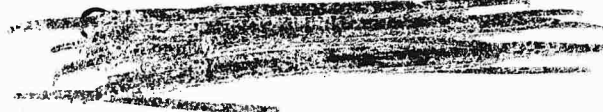
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(TITLE UNCLASSIFIED)

**DRAG FORCE TESTS
ON A LENTICULAR SHAPE
IN TUNNEL HOTSHOT 1**

By
William Wolny
VKF, ARO, Inc.

October 1960

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**ARNOLD ENGINEERING
DEVELOPMENT CENTER**

AIR RESEARCH AND DEVELOPMENT COMMAND



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October 1960

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ABSTRACT

Drag measurements were made on a lenticular shaped body at Mach numbers from 17 to 20 at zero angle of attack. A trend was established for the effect of viscous interaction on the measured drag.

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NOMENCLATURE

C_{D_0}	Drag coefficient at zero angle of attack, drag/qS
c	Chord length, maximum diameter, in.
M	Mach number
q	Dynamic pressure, $\rho V^2/2$, psia
Re	Reynolds number, based on model diameter
S	Model reference area, based on model diameter, in. ²
t	Maximum model thickness, in.
V	Velocity, ft/sec
α	Angle of attack, deg
ρ	Free-stream density, atm

INTRODUCTION

A lenticular shape was tested for the Air Proving Ground Center (APGC), Eglin Air Force Base, Florida in Tunnel Hotshot 1 of the von Karman Gas Dynamics Facility, Arnold Engineering Development Center (VKF-AEDC) from July 22 to August 4, 1960. The objective of the test was to obtain aerodynamic drag data at Mach numbers from 17 to 20 at zero angle of attack.

APPARATUS

WIND TUNNEL

Tunnel Hotshot 1 (Fig. 1) is a hypervelocity, blowdown wind tunnel with a 16-in. -diam test section. In these tests nitrogen, initially confined to the arc chamber, was heated and pressurized to approximately 3000°K and 1000 atm by generating an electric arc in the chamber. The heated gas then expanded through a conical nozzle into the test section where Mach numbers of approximately 20 were obtained. Additional description of this tunnel is included in Ref. 1. New copper arc chamber liners and new Semicon tungsten throats were used for each run. The arc chamber configuration is shown in Fig. 2.

MODEL

The APGC supplied two models of one configuration (Fig. 3). The models were constructed with a thin outer skin of resin-impregnated fiberglass and were filled with foamed plastic.

INSTRUMENTATION

The aerodynamic drag was measured with a single-component strain-gage balance. The drag force was sensed on the balance centerline which coincided with the model centerline.

Arc chamber pressure was measured with a strain-gage-type pressure transducer. Test section pitot pressure and model base pressure were measured with variable-reluctance transducers.

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A double pass schlieren system was used to obtain the shock pattern about the model on several runs. A typical schlieren photograph is shown in Fig. 4.

PROCEDURE

The test was conducted at Mach numbers from 17 to 20 at nominal initial stagnation pressures of 16,000 psia and temperatures of 3000°K. Nitrogen was used as the test gas. For this test the Reynolds number, based on model diameter, varied from 154,000 to 413,000. A run log is presented in Table 1.

Four runs were made with 0.089-in. -diam throats and three with 0.125-in. -diam throats to provide variation in the free-stream conditions. A typical oscillograph trace is shown in Fig. 5.

RESULTS

The measured drag coefficient at zero angle of attack versus M^3/\sqrt{Re} for the lenticular shape is shown in Fig. 6. The trend in variation of viscous drag with this parameter is consistent with flat plate theory and data reported in Ref. 2. The experimental drag value at Mach 8 (Ref. 3) is shown in Fig. 6 for comparison with the Hotshot 1 data.

REFERENCES

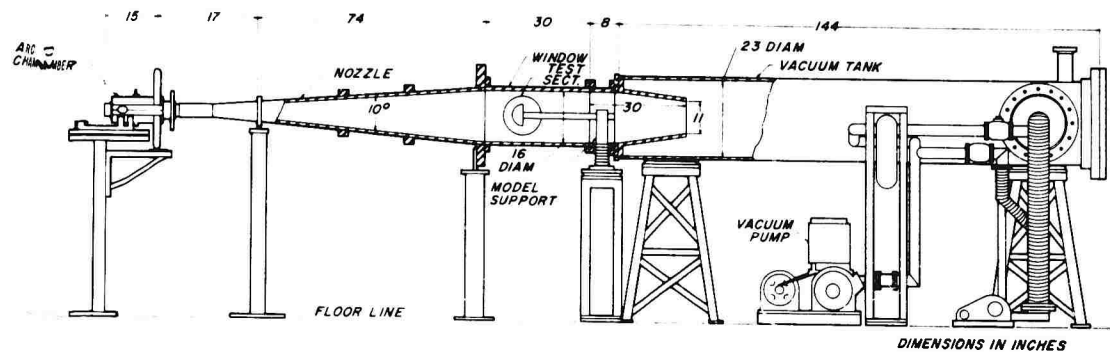
1. Test Facilities Handbook, (2nd Edition). "Gas Dynamics Facility, Vol. 4." Arnold Engineering Development Center, January 1959.
2. Bertram, Mitchell H. "Boundary Layer Displacement Effects in Air at Mach Numbers of 6.8 and 9.6." NASA-TR-R-22, 1959.
3. Kayser, L. and Hillsamer, M. "Longitudinal Stability and Control Characteristics of a Lenticular Model at Mach No. 8." AEDC-TN-60-163, August 1960. (Secret)

TABLE 1

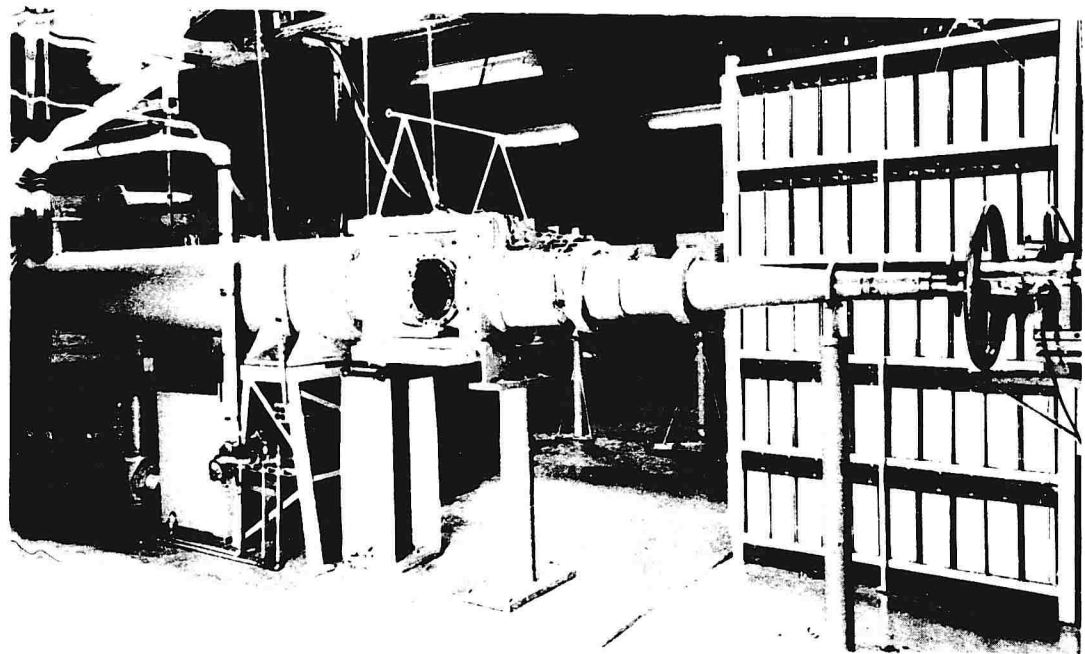
RUN LOG OF FREE STREAM CONDITIONS

Run No.	Mach Number	Reynolds Number* x 10 ⁻³	Density, atm	Velocity, ft/sec	C _{Do}
1576	17.51	413	2.39 x 10 ⁻³	7.43 x 10 ³	0.0292
1577	19.50	154	0.86	8.73	0.0377
1578	17.87	391	2.15	7.41	0.0305
1580	19.07	161	0.95	8.73	0.0356
1582	19.44	161	0.89	8.59	0.0362
1583	17.20	254	1.78	8.28	0.0246
1584	17.17	261	1.82	8.30	0.0254

*Reynolds number is based upon a model diameter of 6 in.



Assembly



Arc Chamber, Nozzle, and Test Section

Fig. 1 Tunnel Hotshot 1, a 16-in.-diam Hypervelocity Wind Tunnel

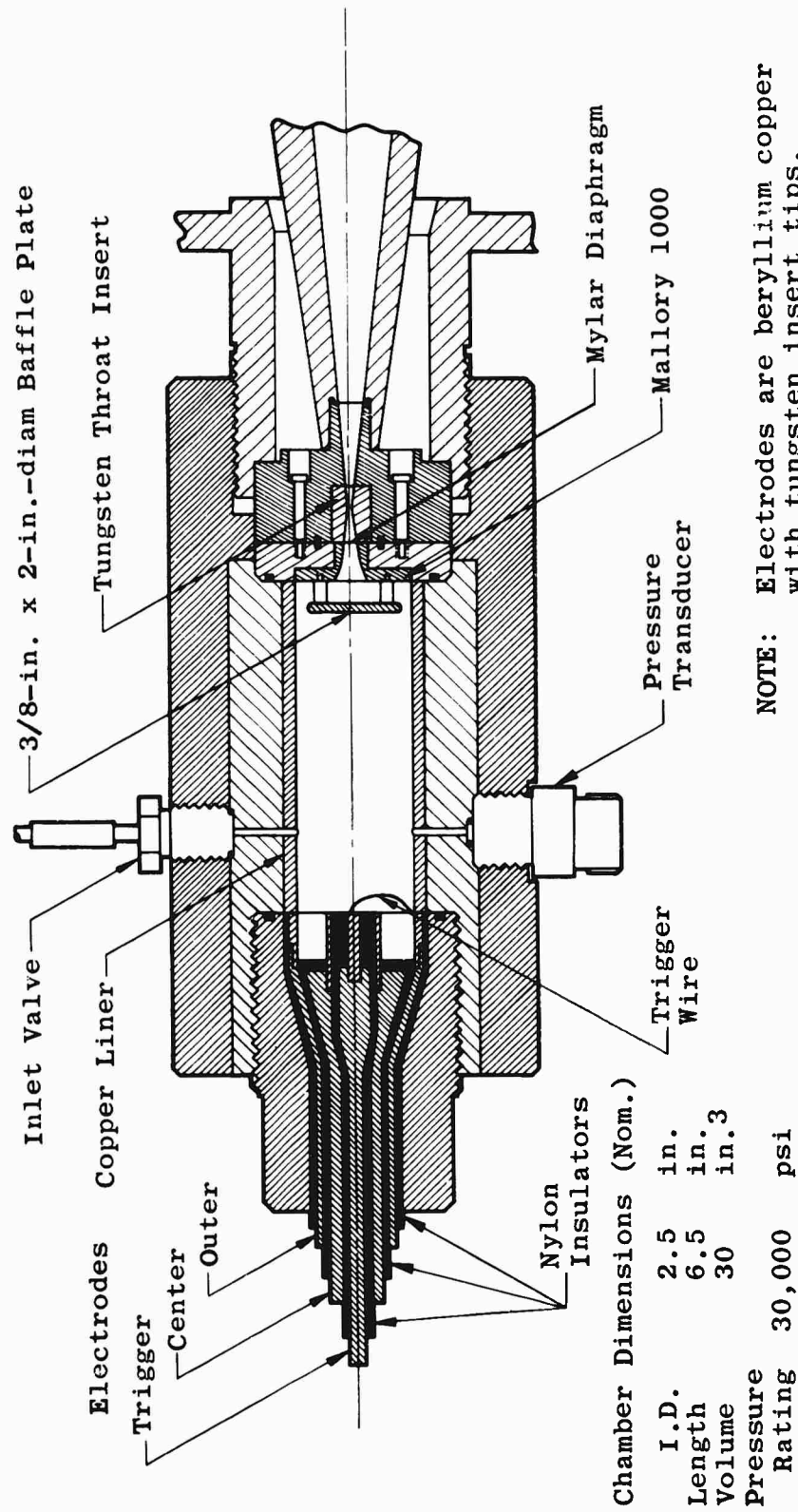


Fig. 2 VKF-16-C Arc Chamber and Throat Assembly

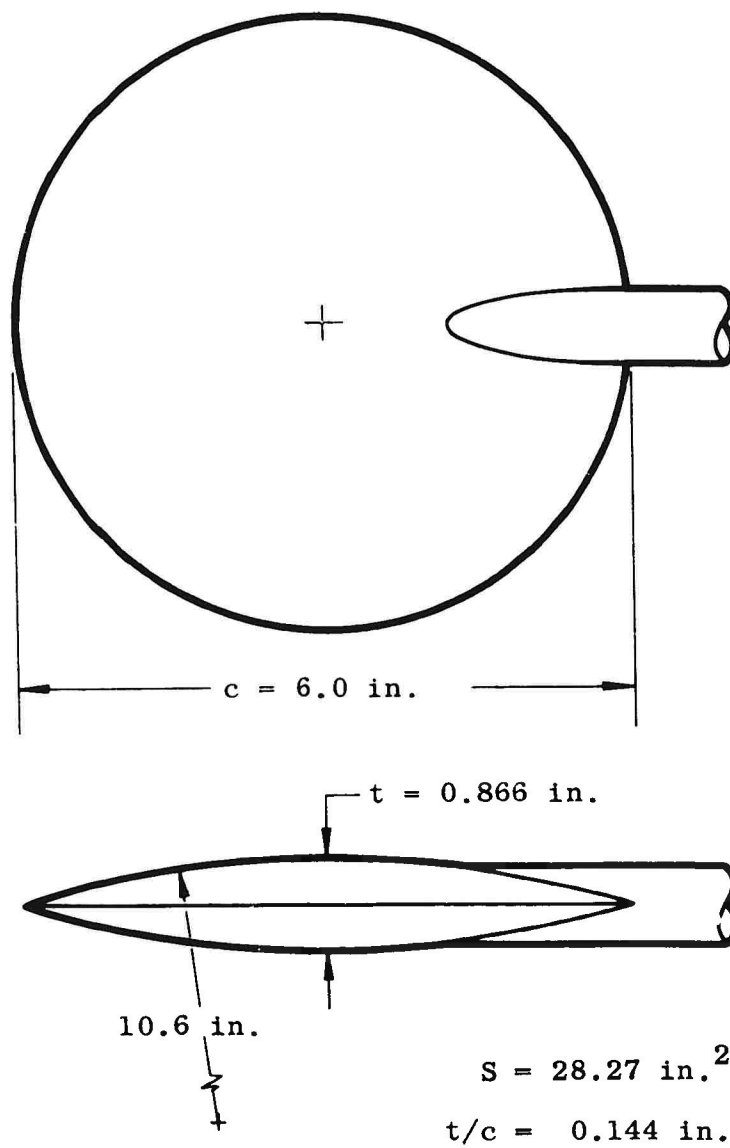


Fig. 3 Model 1C



Fig. 4 Typical Schlieren in Hotshot 1; $M = 17.5$, $Re = 413 \times 10^3$

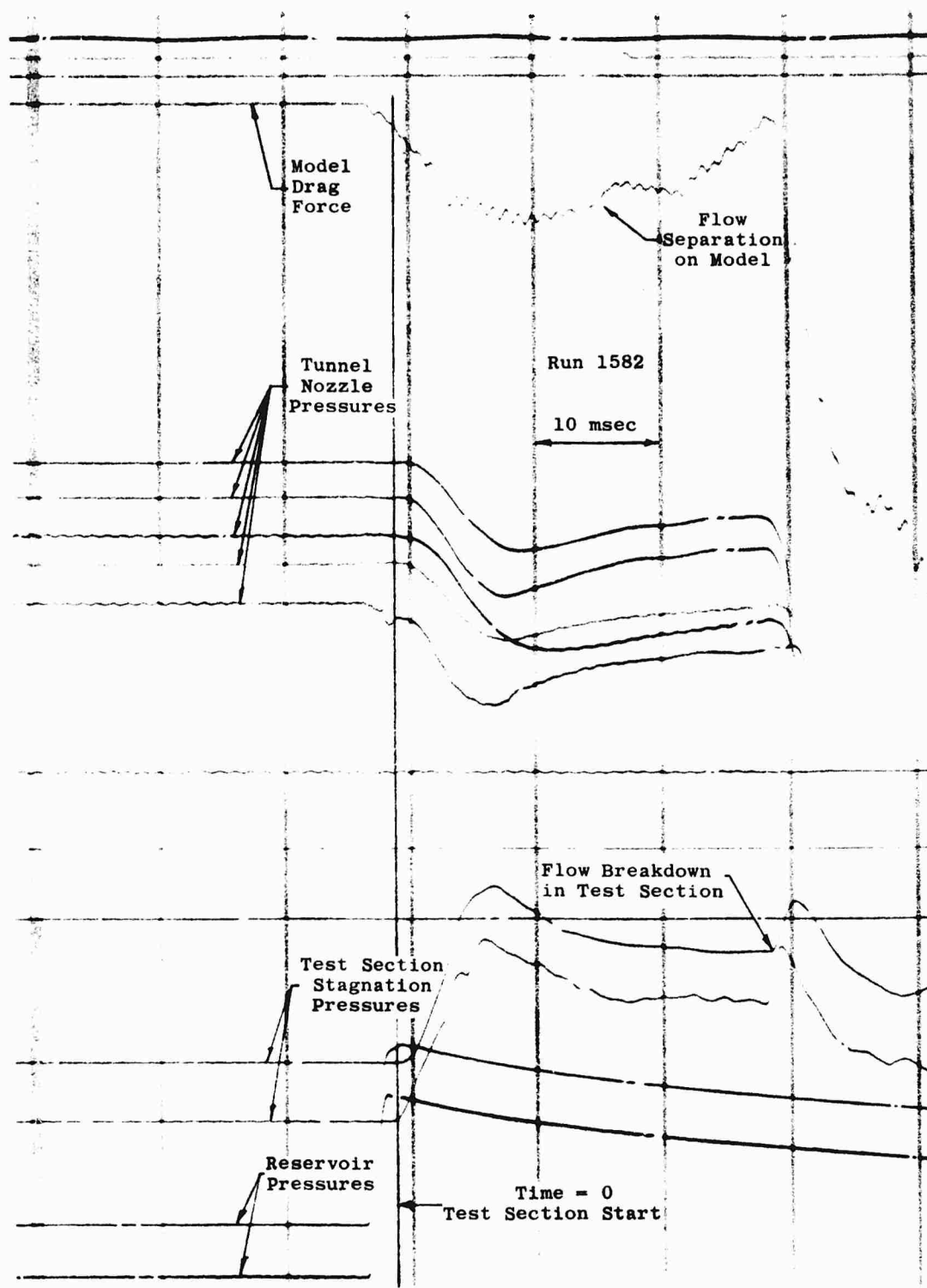


Fig. 5 Typical Oscillograph Trace

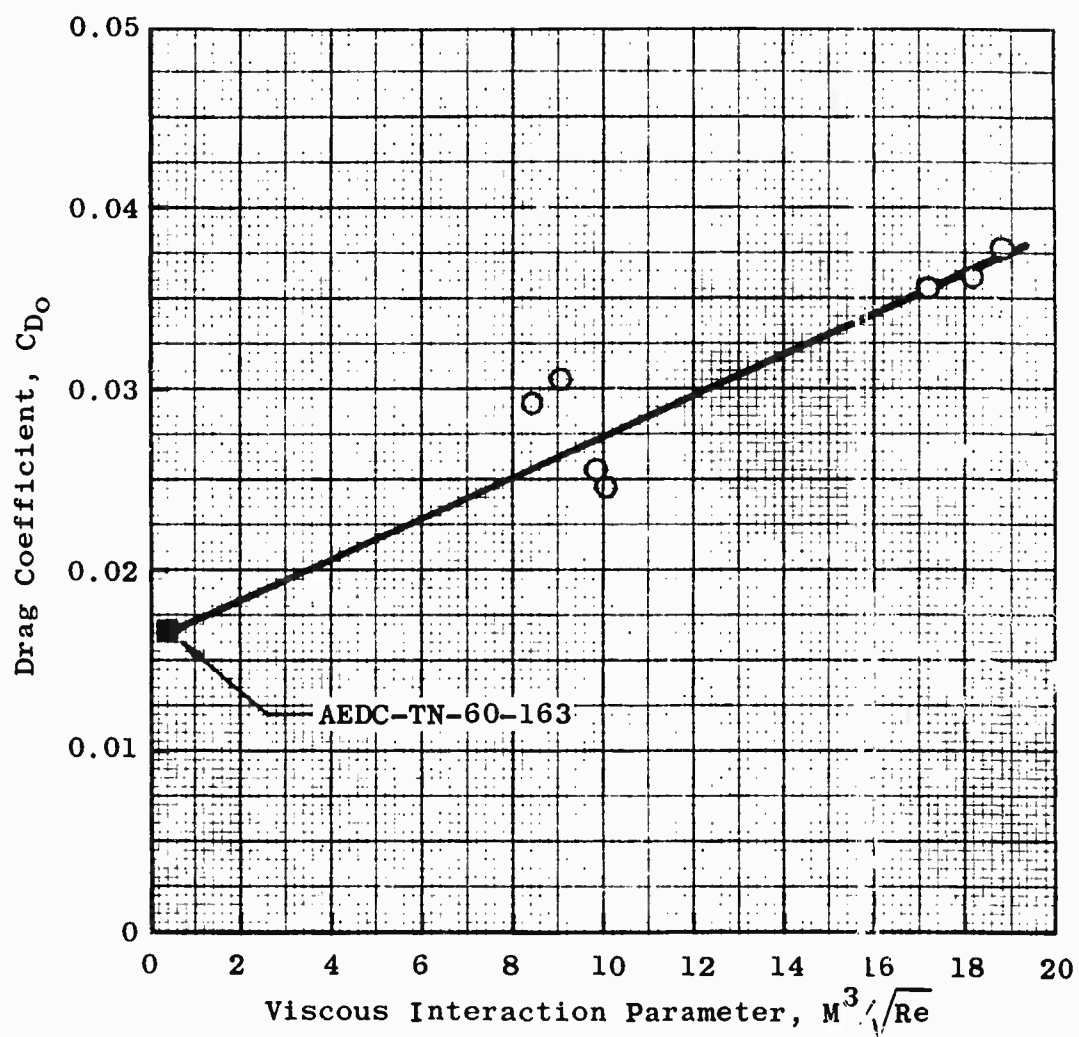


Fig. 6 Drag Coefficient Trend with Viscous Interaction Parameter : $\alpha = 0$ deg